Nanofabrication Based on Template Synthesis for Sensing and Magnetism Applications

Scientific Achievement

The composition and intrinsic nature of anodized aluminum oxide (AAO) templates are important for surface modification and further functionalization. Understanding how the nanopore array forms through "self assembly" is essential to the design of new templates. We found, through controlled etching of an AAO membrane, an underlying double hexagon nanostructure that has domains of pure alumina and acid-anion doped alumina. The etching rate for the doped area is significantly faster than that of the pure alumina. In addition, with use of *in-situ* small angle x-ray scattering technique, the growth of the nanopores was monitored in real time. Under a constant anodization potential, the lateral pore-to-pore distance is always fixed and the nanopores only grow along the vertical direction as a function of the square root of the etching time. These templates were used to prepare Pd nanotubes for hydrogen sensing. We also discovered an AAO nanowell structure that is an array of shallow indents on aluminum surface. When evaporated with a thin layer of Pd, the Pd/AAO nanowells became a highly sensitive and fast hydrogen sensor comparing to the conventional Pd thin film sensor.

Significance

The AAO template composition and the etching rate study will allow one to control the pore opening precisely. These membranes can be used as a new candidate for catalyst support, templates for chemical sensors, shadow mask for lithography, and preparation of nanowires, nanotubes, and nanowells. The pore growth *in-situ* studies will help us to develop new templates with smaller and larger pore diameters that are difficult to prepare directly. Our "template based hydrogen sensors" has led to one publication (*Chem. Mater*. **2005** *17* 3445), one ANL invention report, and one NSF sponsored engineering application of hydrogen sensors for corrosion prevention research project. The AAO templates are also being used to prepare advanced core-shell nanowires for soft-hard composite nanowires with optimized magnetic properties and multi-segment nanowires for novel giant magnetoresistance (GMR) and memory devices.

Performers

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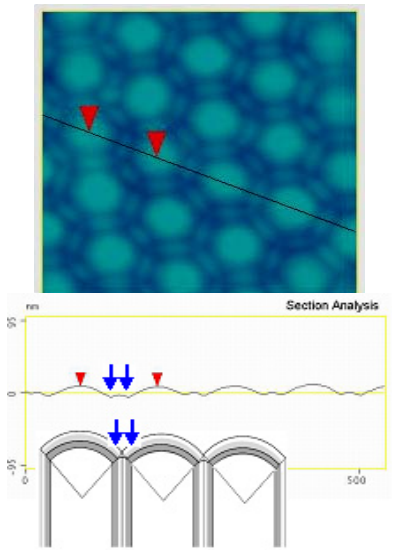
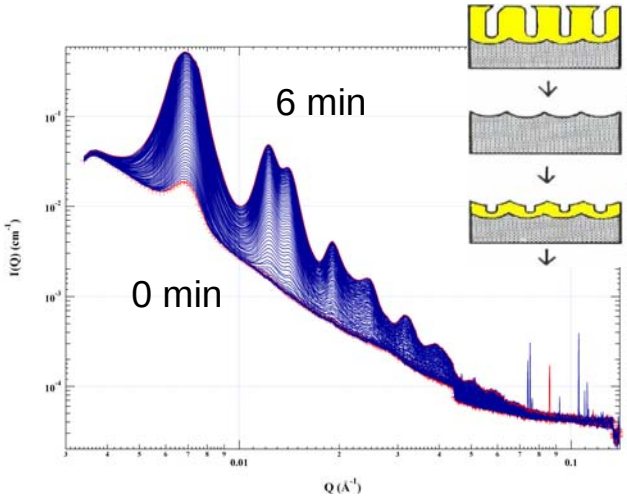
- **AAO Template structure**



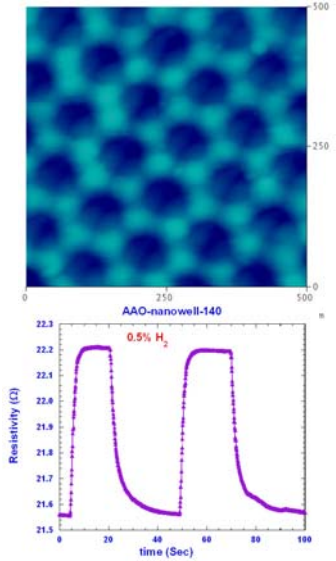
Top, AFM image of AAO template barrier side. Below, the double hexagon pattern is due to the underlying pure alumina (white) and anion doped alumina (gray).

- **Template growth in real time**



In-situ small angle x-ray scattering reveals the nanopore growth for the first 6 minutes. Under constant potential, the pores do not expand laterally. They only grow vertically as a function of $\sqrt{t}$. The study helps us to develop new templates.

- **Pd/AAO nanowell H_2 sensor**



Top, AFM image of AAO nanowells with 75 nm diameter and 20 nm depth. Upon deposition of a 10 nm Pd thin film, the nanowells turned into a very fast hydrogen sensor.

AAO based nanostructures lead to sensing, photonic, and nanomagnetism applications.

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